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ABSTRACT

The purpose of this research was to explore the usefulness of metaphor generation and analysis as a tool for reflection by prospective elementary teachers of science. An interpretive case study was conducted to investigate the changing beliefs of four prospective teachers about science learning and teaching. The main assertion that emerged from the analysis was "reflection through metaphor helped prospective teachers identify and actualize some of their beliefs about learning and teaching science, but the extent depended on their personal histories as science learners and their cooperating teachers." In light of this, it seems that if prospective teachers need to make their implicit beliefs explicit before they can consider learning theories and teaching strategies as presented within their teacher education programs, then they need to be encouraged to do so within reflection. To help prospective teachers make their implicit beliefs about teaching and learning explicit so those beliefs can grow and develop into consistent actions throughout their personal and professional careers, metaphor may be a useful tool for the kind of reflection that connects learning and teaching. Underlying this whole process of learning to teach science is the learning-to-teach environment as influenced by the cooperating teacher. Prospective teachers apparently need safe and supportive learning-to-teach environments where they can become confident to learn to teach science under the mentorship of cooperating teachers who understand contemporary perspectives on children's science learning as well as how prospective teachers learn to teach. (Author)

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METAPHOR: A TOOL FOR MONITORING PROSPECTIVE ELEMENTARY TEACHERS' DEVELOPING METACOGNITIVE AWARENESS OF LEARNING AND TEACHING SCIENCE

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METAPHOR: A TOOL FOR MONITORING PROSPECTIVE ELEMENTARY TEACHERS' DEVELOPING METACOGNITIVE AWARENESS OF LEARNING AND TEACHING SCIENCE

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Abstract

The purpose of this research was to explore the usefulness of metaphor generation and analysis as a tool for reflection by prospective elementary teachers of science. An interpretive case study was conducted to investigate the changing beliefs of four prospective teachers about science learning and teaching. The main assertion that emerged from the analysis was 'reflection through metaphor helped prospective teachers identify and actualize some of their beliefs about learning and teaching science, but the extent depended on their personal histories as science learners and their cooperating teachers.' In light of this, it seems that if prospective teachers need to make their implicit beliefs explicit before they can consider learning theories and teaching strategies as presented within their teacher education programs, then they need to be encouraged to do so within reflection. To help prospective teachers make their implicit beliefs about teaching and learning explicit so those beliefs can grow and develop into consistent actions throughout their personal and professional careers, metaphor may be a useful tool for the kind of reflection that connects learning and teaching. Underlying this whole process of learning to teach science is the learning-to-teach environment as influenced by the cooperating teacher. Prospective teachers apparently need safe and supportive learning-to-teach environments where they can become confident to learn to teach science under the mentorship of cooperating teachers who understand contemporary perspectives on children's science learning as well as how prospective teachers learn to teach.

Conceptual Framework

This study of learning to teach elementary science emerged from a concern in teacher education that prospective teachers do not find their teacher preparation courses particularly helpful in their development as teachers (Calderhead & Robson, 1991; Kagan, 1992; Zeichner & Gore, 1990). Prospective teachers typically enter a teacher education program with at least 15 years of experience as science learners in classroom settings where *learner as absorber of knowledge* with *teacher as transmitter of information* were dominant metaphors for learning and teaching (Northfield, Gunstone, & Erickson, 1996).

Teacher Education

Before one can change her or his beliefs, one has to realize what those beliefs are. In 1968, Asubel stated, "The most important single factor influencing learning is what the learner already knows" (cited in Treagust, Duit, & Fraser, 1996, p.1). Since learning is strongly influenced by prior knowledge, instruction must begin by helping the learner articulate what he or she already understands and believes. Kagan (1992) concluded that a problem with many teacher education programs is they do not encourage novices or preservice teachers to make their personal beliefs explicit. Previous studies have suggested that until extant beliefs about learning and teaching science are made explicit, it is unlikely that they will mature within a prospective teachers' preparation program (Kagan, 1992; Treagust, Duit, & Fraser, 1996).

Some of the common beliefs of elementary teacher candidates that need to be made explicit and changed are the primarily resistant conceptions of how science is learned and consequently should be taught (Stofflett, 1994). Teachers tend to teach as they were taught and a large number of preservice teachers have, for the most part, experienced a didactic model of science teaching. That often does not include an explicit goal of student learning with understanding. For preservice teachers to move from short-term, rote learning to a longer-term and deeper understanding of science concepts, they need to undergo a conceptual change themselves (Stofflett, 1994).

Specifically, Prawat (1992) noted some predominant beliefs among teachers that often get in the way of adopting a constructive approach to teaching and learning. First, when the learner and content are viewed as static, non-interactive entities, more time and attention is spent on delivery or teaching than on student learning. This is typically where preservice teachers remain for possibly years into their practice until they may eventually begin to consider the meanings learners are constructing. Second, there is a tendency toward "naive constructivism" (Prawat, 1992, p. 357) which results in equating activity with learning. Dewey (1938) argued that student engagement should not be used as the best measure of educational value.

The conceptual change model, developed by Posner and later modified by Hewson, is a way of thinking about science learning from a constructivist viewpoint (Hewson & Hewson, 1988). In this model, learning begins for the individual at a point based on what the student already knows. Teachers cannot be constructivist teachers when they have not been constructivist learners (Stofflett, 1994). If preservice teachers experience conceptual change content learning experiences themselves, they might become dissatisfied with how they were taught science and seek more constructivist models of teaching science (Thorley & Stofflett, 1996). If they understand the new model (intelligibility), find it consistent with their new beliefs about learning (plausibility), and endorse its usefulness for teachers (fruitfulness), preservice teachers may

undergo a pedagogical conceptual change and adopt this model as a way of approaching instruction (Martens & Crosier, 1994).

Reflection

Conceptual change will not occur unless students are conscious of their thinking (Martens & Crosier, 1994). One element to promote this sort of consciousness is collaborative, self-reflective inquiry (Tabachnick & Zeichner, 1994). Beliefs and ideas about science teaching and learning can be made explicit through reflection. Dewey (1933) called reflection the hallmark of intelligent action and suggested we learn more from reflection on our experiences than we do from the actual experience. In this sense, reflection is more than just talking about ideas; it leads to doing something about them in a classroom. Student teachers need to become reflective practitioners to metacognitively improve their understanding of their practice (Gunstone, Slattery, Baird, & Northfield, 1993). It is through this metacognitive activity that the focus moves from self or teacher behaviors to students and learning (Stofflett & Stefanon, 1996). This shift may not be as developmental as once thought, suggesting that teacher education programs that help develop reflective practitioners could have an impact on shifting the focus of prospective teachers from self and teaching to students and learning.

Metaphor

One vehicle to prompt and assist reflection is metaphor. The term metaphor comes from a Greek word meaning "to carry across" (Schon, 1979). This implies the rich vocabulary developed for one experience can be used to describe another. Lakoff and Johnson (1980) have concluded that the value of metaphor is understanding a new experience in terms of a more familiar one. They argue the human conceptual system is defined and structured metaphorically, and human thought processes are largely metaphorical. In other words, humans make sense of new information by directly relating it to personal experiences and prior knowledge.

To learn, one needs to make sense of an unfamiliar situation. Through metaphor, one personalizes one's understanding by relating new information directly to personal experience and knowledge, and thus offers a path or vehicle for learning about one's thinking. In this way, metaphor is both a product – a way of looking at things – and a process by which new perspectives are constructed (Schon, 1979). It can be either, but in this study, the focus is on product and how reflection through metaphor indicates conceptual change and conceptual growth. Reflection through metaphor might prove an interesting way to study changes in teacher conceptions of science, learning, and teaching, and also facilitate the sorts of changes in thinking that science educators hope to see within prospective teachers over the course of a teacher preparation program.

Several studies have indicated that reflection through metaphor can be a means by which preservice teachers come to terms with experience (Bullough & Stokes, 1994; Shapiro, 1991; Tobin, Tippins, & Hook, 1994). All new knowledge is filtered through a teacher's framework of beliefs which have developed over a lifetime of experiences, both in and out of the classroom (Briscoe, 1991). Personal theories are formed by teachers as related to practice; however, much of this pedagogical knowledge is tacit. From a constructivist view of learning, the impact of typical teacher education is questioned because teacher educators typically ignore the novice's prior knowledge about teaching (Bullough, 1991). Here, metaphors can be used during reflection as prospective teachers assign language to these otherwise nonlinguistic constructs.

Within a teacher education program, prospective teachers should be encouraged to think, argue, act, and interact in increasingly more effective ways with learners through more experienced teachers who are their mentors. Through observation of learning environments and then through their own practice and reflection, prospective teachers can perhaps better understand their own teaching beliefs and roles through the metaphors they craft to identify their role within a particular situation (Tobin, 1990). Each individual has beliefs about roles for herself or himself (Lorsbach, 1995). These beliefs may govern how an individual acts in a special situation and also the meanings assigned to the actions of others. If reflection through metaphor accompanies changes in action within practice, then reflection through metaphor can serve as a foundation for teachers to better understand conflicts in embedded beliefs and classroom practices, and perhaps better identify where change is needed and why.

Using metaphors represents an explicit comparison and interaction among conceptual representations of content, pedagogy, students, self, and classroom actions (Tobin & LaMaster, 1996). After a lesson and during reflection, the prospective teacher can become more metacognitively aware of her or his own beliefs and actions through examining metaphors for functionality. Being accountable for functional or nonfunctional metaphors is empowering. Being empowered is taking responsibility for one's own learning, one's own lifelong learning. Reflection through metaphor could provide a new vision for some prospective teachers to do just that.

Purpose and Guiding Questions

Given that beliefs of learning and teaching science held by prospective teachers need to be made explicit before they can be changed and that reflection through metaphor is a way of looking at a situation or problem differently helping to make implicit beliefs explicit, a purpose started to emerge. The purpose of this study became to explore metacognition in prospective teachers of science through reflection featuring metaphor generation and analysis. This purpose led to the

following research questions: (1) How do beliefs about learning and teaching science in prospective elementary teachers change, as reflected through metaphor, over their yearlong field experiences? (a) How do they view the role of hands-on experience or activity within a science curriculum? (b) Do they distinguish between rote science learning and meaningful learning? (c) What is their understanding of the relationships between student learning and their teaching? (2) In what ways do prospective elementary teachers' metacognitive awareness of learning about teaching science change over their yearlong field experiences as reflected through metaphor? (a) How does reflection through metaphor make beliefs about teaching and learning explicit? (b) How does reflection through metaphor change? (c) How does reflection through metaphor capture alternative beliefs?

Methods of Inquiry

This study began as an attempt to understand meanings that prospective elementary teachers of science were making about various issues in science education during their field experiences. It was done within the theoretical framework of phenomenological inquiry allowing grounded theory to emerge. Centered around an interpretive case study design, the four participants were purposefully selected as ones who enjoyed the use of metaphor within reflection. Data were collected over the most intense period of their field experiences, pre-student and student teaching. This covered two semesters and included pre-student teaching (ten weeks, two days per week) and student teaching (15 weeks, full time).

To encourage students to identify and reflect upon their ideas, metaphors were used. Primary sources of data included interview transcripts, reflective journals, and documents produced for coursework. Secondary data included the researcher's field notes and journal, and videotaped teaching episodes. Data were analyzed inductively with coding strategies allowing for assertions to emerge. Individual within-case analysis was followed with a cross-case analysis of all four participants.

Phenomenology

Phenomenology was chosen as a method of inquiry because it is concerned with uncovering the essence of one's experience of a phenomena as well as structures of consciousness that allow people to make meaning (Patton, 1990). First used as a philosophical tradition by Husserl, its basic philosophical assumption is that we can only know what we experience by attending to perceptions and meanings that awaken our conscious awareness. As prospective elementary teachers begin and progress through their field practica, they experience a phenomenon, the process of becoming a teacher, within the world of the classroom. From the perspective of

phenomenology, the focus or essence to be discovered is how sense is made of that process of forming and changing beliefs. It is through the learning and teaching experiences in the classroom that meanings are derived and personally constructed for words and phrases used in theory and coursework. These include experience or activity, meaningful learning, and how one's teaching of science is driven by what one thinks about learning science.

To consider the metacognitive aspect of making meaning, metaphors were used as a vehicle or tool and were developed, explained, and reflected upon by the prospective teachers to help them identify their various beliefs about learning and teaching science. As they reflected upon their metaphors and experiences, the interpretive processes of the prospective teachers led them to discover new meanings for their experiences within the culture of the classroom. Through discussing their metaphors, the prospective teachers were able to make some of their beliefs explicit, reflect upon those once they were apart from them via a metaphor, and then, through changed or evolving metaphors, consider other perspectives or ideas. This was all part of the metacognitive processes of the prospective teachers as they came to more fully understand their teaching in light of students' learning.

Grounded Theory

Because grounded theory is inductively derived from the study of the phenomenon it represents, it was also chosen as a guiding framework for this study (Strauss & Corbin, 1990). Instead of beginning with a theory then proving it, one considers the study as a whole and allows certain theories to emerge. Specifically, there are four central criteria for judging the applicability of theory to a phenomenon. The theory should be induced from the data and be faithful to or fit the everyday reality of the substantive area. Since it represents that reality, the emerging theory should be understandable or comprehensible to the participants and practitioners in the field. Third, the interpretation of this theory should allow for some generalizability and applicability to other areas related to that phenomenon. Last, the conditions should be controlled to the point they apply specifically to a given situation.

Interpretive Case Study

With the purpose of determining the ways in which four prospective elementary teachers, through reflection including metaphor, changed their metacognitive awareness about learning to teach science, an interpretive case study design was chosen. Case studies are particularly useful when one is attempting to understand a particular situation in depth and when one can identify information-rich cases to facilitate this understanding (Patton, 1990). To understand the process of

becoming a teacher, one needs to understand in depth how individuals are learning and making sense of their experiences as teachers in the field.

To attempt to answer the research questions, the case study approach was used to drive the collection, organization, and analysis of data (Patton, 1990). General and individually specific questions were generated for interviews to gather comprehensive, systematic, and in-depth information and uncover particular beliefs about learning and teaching from each participant.

Coding

To build theories, based on the use of metaphor by prospective elementary teachers to help them make meaning of their personal conceptual changes as they experienced their field practica, three major types of coding was used; open coding, axial coding, and selective coding (Strauss & Corbin, 1990). After reading the complete data set, open coding was done which is the process of breaking down, examining, comparing, conceptualizing, and categorizing the data. This was followed by axial coding, a set of procedures whereby data are put back together in new ways by making connections between categories. Selective coding is the process of selecting the core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development.

Assertion Building

As the data were being collected and analyzed, assertions were being generated. These assertions, both descriptive and inferential, were validated repeatedly by reviewing the data and seeking disconfirming and confirming evidence (Erickson, 1986). Data were first analyzed by specific cases for in-depth analysis which included the construction of vignettes or case study narratives for each participant from each set of raw case data. Common themes or assertions were allowed to emerge. These individual within-case analyses are reported in-depth elsewhere (Sillman, 1998). In addition to capturing individual stories through within-case analysis, a cross-case analysis of all four participants was also used to answer the research questions.

Cross-Case Analysis: A Human Construction

The purpose of this study was to determine, through reflection including metaphor, the ways in which four prospective elementary teachers changed their metacognitive awareness about learning to teach science. While the goal of the last year of formal teacher preparation was the same for all four participants, that of learning to teach, the process was unique to each of the participants. The process of learning to teach resembled a human constructivist view of learning. Novak has synthesized a comprehensive view of meaning that encompasses a psychological model

of human learning and knowledge restructuring together with the analytical and explanatory potential within a unique philosophical perspective on conceptual change (Mintzes & Wandersee, 1998a).

This view is summarized in three assertions. First, humans are meaning makers and do so by forming connections between new concepts and those that are part of an existing framework of prior knowledge (Mintzes & Wandersee, 1998a). The human constructivist would assert that no two humans would construct the same meaning from identical phenomenon. Second, knowledge is a dynamic construction of human beings. Third, the construction of shared meanings can be facilitated by the active intervention of well-prepared teachers.

The participants constructed their own meanings of the phenomenon of learning to teach science specifically and learning to teach in general through their pre-student teaching and student teaching field experiences. The prospective teachers constructed those meanings through varying amounts of reflection, both individual and with cooperating teachers, supervisors, university instructors, parents, other prospective teachers, and me as instructor / researcher / collaborator. Also facilitating their meaning constructions was the use of metaphor in reflection both with me and individually. Table 1 shows the summaries of the predominant uses of the concept codes in the cross-case analysis. Figure 1 summarizes the assertions from the collective processes of learning to teach science as suggested through analysis of the concept codes. Table 2 shows the metaphors crafted by the prospective teachers during reflection.

Assertion 1: Reflection with metaphor helped prospective teachers realize their beliefs and changing beliefs, some of which guided their practice.

The four participants were purposefully selected for this study because they enjoyed using metaphor to define and explain roles for learner and teacher at the beginning of their pre-student teaching field experience. Likewise, they continued to enjoy using metaphor as they progressed through their student teaching field experience and to the completion of this project. They all felt metaphor helped them make their beliefs explicit and, as they experienced teaching and reflected upon those beliefs, helped them to develop and even change some of those beliefs.

1a. Reflection through metaphor helped prospective teachers make their beliefs explicit.

During the first half of this study which took place while the prospective teachers were in methods courses (including courses in teaching and learning social studies, mathematics, and science), this study focused on learning to teach science. Through reflection with metaphor, several important beliefs about learning and teaching science were made explicit. These included

the importance of experiencing a conceptual change, providing hands-on experiences, developing critical thinking skills, and providing a safe learning environment.

Identify Beliefs with Metaphor: Conceptual Change

Early in his last year of formal teacher preparation within his elementary science methods course, Matt experienced a conceptual change lesson on density. He himself began to undergo a conceptual change in how science should be learned and therefore, taught. For science concepts to be learned, Matt felt his learners needed to undergo a conceptual change themselves as he had begun to experience. His new beliefs about science learning were evident in the metaphors he crafted for phases of the conceptual change model used in the lesson.

Matt was *learner as excited child* to express the safe, risk free environment he felt he had and needed in order to learn: "I felt like a kid in a candy store. . .for one time in my life, I was allowed the freedom to test materials in my own way and wasn't embarrassed to show my excitement or enthusiasm" (Instrument Tool 1, 9/26/97). Next, he crafted *learner as light bulb*: "During this phase of the lesson, I could feel the light bulb going off in my head. I was making the connections. . .I learn a lot from other people. . .somebody made a comment and the light bulb went off" (Instrument Tool 1, 9/26/97). Here, Matt expressed how he and other learners make connections through hands-on experiences and through social interactions with others. Third, he was *learner as amazed* to emphasize that learning happens when one experiences a concept instead of just hearing about it: "I was amazed at this because although I heard about this separating many times, I had never experienced it" (Instrument Tool 1, 9/26/97). In summary, when Matt was able to feel safe about taking risks and experiencing a concept through hands-on activities, he was able to learn on his own and through others, and he felt more confident to continue learning.

Learning science in this way seemed to be new for Matt and most of the prospective elementary teachers. Likewise, experiencing conceptual change lessons seemed to be an important part of helping the prospective teachers begin to undergo a conceptual change themselves in how science is learned and taught. However, it was only a beginning.

Identify Beliefs with Metaphor: Hands-on Experiences

As the prospective teachers progressed through their last year of formal teacher preparation, the importance of providing hands-on experiences for learners became apparent. Early in her pre-student teaching field experience when she created and implemented a conceptual change teaching project, Carrie realized one of the most important beliefs for her of learning and teaching, the power of experience through hands-on activities in learning science. To express this, she crafted

the metaphor *teacher as trunk or branches of a tree* which she also referred to as *provider of experiences*.

She also realized the importance of the teacher in providing those experiences that individual students needed to learn when she commented after a lesson on pumpkins: "A lot of them, this was the day before Halloween and they didn't even have jack-o-lanterns, didn't even have pumpkins at their houses. . .a lot of them never had felt one before" (Interview 1, 10/22/97). Carrie realized what those students were missing: "They never realized it has ridges, or it's kind of heavy but when you knock on it, it still sounds a little hollow inside. . .That was an important revelation for me, to know that not everybody received this opportunity" (Interview 1, 10/22/97). At the end of her pre-student teaching experience, Carrie still felt this experience was a revelation for her: "I left the school that day with a new view on life and teaching. I can see that providing students with meaningful, hands-on experiences is the most valuable gift I can give to my students" (Lesson Reflections, 11/26/97).

An important belief for the prospective teachers about learning and teaching science was to provide meaningful, hands-on experiences for their learners. One teacher crafted the metaphor to describe his role: "*Teacher as stagehand*. . .because I would just say because of the added amount of instruction and guidance you have to give" (Interview 2, 3/5/98). He elaborated: "I just get this vision of setting up the scenery and all the props in the exact right spot" (Interview 2, 3/5/98). Matt emphasized the importance of planning and organization when using hands-on activities, especially at the younger grade levels. Without constantly having planned activity, students would have the opportunity to make too many of their own plans that might not include meaningful learning of the concept in focus.

Identify Beliefs with Metaphor: Critical Thinking

However, the prospective teachers also realized hands-on activities alone were not enough. The development of critical thinking skills were crucial to a science learner and a science teacher who was not falling prey to "naive constructivism" (Prawat, 1992, p. 357) which results from equating activity with learning. Within her pre-student teaching field experience, Nancy used hands-on activities as the teacher and focused on questioning skills to encourage thinking. Through *teacher as facilitator of thinking*, Nancy encouraged independent thinking within her learners. Upon reflection, Nancy changed her metaphor to *teacher as connection maker* as she began to concentrate more on the outcome of thinking, that of the students building connections. Another prospective teacher commented: "Children need practice using processes and skills. If children are proficient in their use, any and all science content will become available to them" (Post-philosophy, 12/10/97).

Identify Beliefs with Metaphor: Safe Learning Environment

All prospective teachers stated the importance of a safe environment for learning. After experiencing and crafting metaphors for each phase of the conceptual change model used within a conceptual change lesson in her elementary science methods class, Nancy came to realize her implicit beliefs about learning included a safe, risk free environment for learning. Through *learner as blank slate*, she explained how her anxiety prevented her from thinking and learning: "When you asked us to apply it, I feel I didn't know. My mind just went blank. . .I'm not used to having to apply what I learned. . .I'm just not used to it" (Interview 1, 10/17/97). Along with being free from anxiety, Nancy also realized that for her to learn, she had to use and apply the concepts.

As Matt created and implemented a conceptual change teaching project within his pre-student teaching, he reinforced these new beliefs and began to see how useful they were in action. Because Matt felt the teacher needed to provide support, guidance, and direction for learners, he crafted *teacher as runway*: "I think of myself as the base. I think a lot of teachers would think, 'Well, I'm the plane; I fly the students'. . .I prefer to be the *runway*. They'll use me to go to other places" (Interview 1, 10/24/97). With this metaphor, Matt created a safe atmosphere where learners felt free to take risks and learn. Matt also felt the positive encouragement was important to learners in providing a safe atmosphere where they would feel motivated to learn. He crafted *teacher as proud father* to express that and the joy he experienced as a teacher in watching his students experience their own learning. Through her metaphor of *teacher as state park*, Carrie expressed the importance of providing that safe learning environment.

1b. Reflection through metaphor helped prospective teachers realize some important changes in their beliefs, some of which guided their practice.

During the second half of this study which took place while the prospective teachers were in their student teaching placements, reflection with metaphor continued. Several important beliefs about learning and teaching science were modified or realized. These included realizing the importance of student motivation, the foundation that teachers provide for students, students as part of a larger learning community, learning to teach as a lifelong learning process, and constraints on the process of learning to teach.

Identify Changing Beliefs with Metaphor: Student Motivation

As the prospective teachers entered their full-time field experiences, they compared the students in their new classrooms with those in their previous classes. They noticed several differences among students, one of which was student motivation. Within his pre-student teaching field experience, Kris crafted the metaphor, *teacher as business executive*, as he focused on

creating a safe, risk free environment for learning. He explained that just as every department is needed within a business, so is every student's opinion and voice valued in the knowledge construction within a classroom. The students in Kris' pre-student teaching classroom were motivated to learn and the classroom was well managed because Kris felt students were focused on thinking.

Kris entered a different classroom for his student teaching experience. Kris felt the students in this new context were less motivated to learn and were not as used to thinking independently. To achieve his philosophy, Kris had to change his metaphors. Kris had to go to the bottom of his metaphor hierarchy to become *teacher as tour guide*: "This group is unable to handle a large amount of independent thought. My [pre-student teaching classroom] was quite capable of such and was frequently excited by the opportunity to think and figure things out for themselves" (Journal Entry, 1/26/98).

Through this metaphor, Kris guided and motivated his learners to develop critical thinking skills. Once they could learn more independently, Kris became *teacher as business executive* where he could give them more independence to learn together. Ultimately his goal as teacher was the metaphor he created before his field experience, *teacher as one of the students*. Here, the students could reach Kris' goal for them of more independent learning within the student-centered classroom he provided. Kris' metaphors reflected a hierarchy of teaching styles that Kris viewed as being used depending on the type of students in the classroom that he would enter.

Identify Changing Beliefs with Metaphor: Foundation

The prospective teachers came to see more importance and depth in their roles as teachers. This development of beliefs were evident through their metaphors. In general, Matt became much more student-centered in his approach to teaching and learning. First, he crafted *teacher as foundation* as he considered the depth of support the teacher provides for students to feel free to learn. He continued to believe in the power of positive encouragement and crafted three metaphors to explain. Through *teacher as open book*, Matt shared with the students so they would feel more comfortable relating to him. *Teacher as breakfast cereal* expressed Matt's goal of creating a friendly, family atmosphere in the classroom conducive to learning. Matt was *teacher as emotional* when he shared his emotions in hopes of students feeling more free to express their feelings and opinions.

As Nancy became more aware of individual students with individual differences, she saw a larger, more encompassing role, *teacher as quilt*. To her, the different patches represented the various roles teachers needed to be depending on the individual needs of the students.

Identify Changing Beliefs with Metaphor: Learning Community

As the prospective teachers progressed through their last year of formal teacher preparation, they began to see not only a larger role for the teacher, but a larger learning community for the children beyond the classroom. For Carrie, *teacher as state park* became more like the metaphor, *learning community as state park*. Carrie began to realize the importance of involving parents in the emotional and academic well being of the individual learner and crafted a metaphor for them, *parents as park committee*. Through acknowledging this position for parents as a higher authority, Carrie emphasized the need for parents and teachers to support and trust each other to provide the best learning environment possible for the children. As needed, she became *teacher as security guard* or *police officer* to ensure that every child had the opportunity to learn and not be inhibited or distracted by others. To provide that necessary support and positive encouragement, Carrie was *teacher as park ranger* or *gardener*.

Identify Changing Beliefs with Metaphor: Learning to Teach

Prospective teachers also began to see their processes of learning to teach science as a process that would not be completed by the end of the semester. Carrie crafted a metaphor for *learning to teach as an open can*vas: "People in your lives paint on you; the students, your coop, your supervisor, your professors. . .parents. . .it's all in how you look at that canvas and perceive everything. . .and develop on your own what you want from that" (Interview 5, 4/14/98). Here, she expressed that all her experiences, represented by the different paints on her *canvas*, blended to form the teacher that she perceived she was at any given point. Her *canvas* changed during her student teaching as Carrie developed a more student-centered approach to teaching and learning. It would continue to change throughout her teaching and learning career.

Throughout her yearlong field experience, Carrie embraced metaphor as a personal vehicle for making sense of new experiences and deriving her beliefs from her actions. She enjoyed the process enough to begin using it independently. She began developing metaphors in her personal reflective journal entries, which were not required for her coursework or this project. It seemed as if Carrie had found a tool that might help her continue to learn about her growing and changing beliefs throughout her teaching and learning career. As he completed his student teaching, Matt crafted *teacher as one of the students* as he came to perceive teaching as lifelong learning. In learning to teach, Matt felt he had really learned how to learn.

Identify Changing Beliefs with Metaphor: Constraints

Part of what impacted the process of learning to science were constraints as perceived by the prospective teachers. Nancy entered her student teaching with the confidence to teach science.

That diminished as she also entered into a personality conflict with her cooperating teacher. Called into question was who Nancy was as a person and a teacher and resulted in Nancy entering a depression. It also resulted in her being moved to a second placement in another school district with a more traditional cooperating teacher who was supportive of Nancy. However, depressed from her experience, Nancy became *teacher as self-centered* as her learning shut down and she withdrew.

She realized her attitude after reading a vignette of her pre-student teaching experience: "I started really getting upset because you know, I really am not thinking about anybody but myself and that's not what a teacher can do. A teacher can't be *self-centered*. Teaching is almost like a selfless service" (Interview 2, 3/4/98). Nancy focused on herself surviving her field experience and graduating. She realized her egocentrism and the effect it was having on the students. She was not encouraging meaningful learning. Nancy tried to see her students' perspective, but this sensitivity alone was not enough to help her become the science teacher she was in her pre-student teaching.

Assertion 2: Learning to teach science depends on the prospective teacher's personal history as a science learner and on the cooperating teacher.

During the first semester of this study, the prospective teachers focused on science learning in their methods courses and some science teaching in their pre-student teaching field experiences. At this point, they were largely influenced by their prior science learning experiences and to some extent, their current methods courses. Once they entered their student teaching, they were almost exclusively influenced by their cooperating teachers in learning to teach in general and learning to teach science specifically.

2a. How one teaches science depends on how one learned science.

According to Asubel, "The most important single factor influencing learning is what the learner already knows" (cited in Treagust, Duit, and Fraser, 1996, p.1). Therefore, it was important to realize the prospective teachers' existing beliefs about learning and teaching science from their perspectives as learners in order to change or modify them. It was also important to provide meaningful science learning experiences for the prospective teachers as learners of science within their science methods courses.

Learning and Teaching Science: Meaningful

There was an historical element present which affected the prospective teachers' process of learning to teach science and learning to teach in general. Most preservice teachers enter a science

teacher preparation program holding primarily didactic, pedagogical conceptions of science teaching and learning (Stofflett, 1994). From learning in didactic classrooms, science is typically viewed as a body of facts and is taught as such (Acquirre, Haggerty, & Linder, 1990).

One participant in this study entered the teacher preparation program with a strong conceptual understanding of many science concepts probably stemming from his early interest in science: "As a child, I enjoyed science because it offered me the continual challenge of finding reasons. . .finding meanings. . .understanding. . .delighting in the processes of science" (Post-philosophy, 12/10/97). Kris also entered the program with a particular view of science: "Science. . .is a process of inquiry, observation, and experimentation" (Pre-Philosophy, 8/28/97). This view of science as a process is consistent with a constructivist epistemology according to the National Science Education Standards which advocates "Understanding scientific concepts and developing abilities of inquiry" in place of "Knowing scientific facts and information" (National Research Council, 1996, p. 6).

Learning and Teaching Science: Rote

In contrast, most of the prospective teachers in this study entered the teacher preparation program with a more didactic conception of science learning. One participant felt she had as a learner come to abandon meaningful learning for survival and success through rote learning: "I don't have a clue what went on in this class, but I can get an 'A' in your class because I have great rote memorization skills, the ability to sit down and memorize large chunks of information" (Interview 5, 4/13/98). For Nancy, success was obtained through memorization of concepts which yielded good grades: "Biology and chemistry were subjects I did fairly well in, but this was due more to improved memorization skills than any understanding of the materials. It was rare that I ever understood any scientific concepts" (Pre-philosophy, 8/29/97). Unfortunately, conceptual understanding was not part of success in school science for Nancy. This was due largely to the negative experiences she had herself with science teachers who held negative attitudes. Apparently, her prior experiences impacted the way Nancy approached learning to teach science. This seemed to be typical of prospective teachers of science.

Learning and Teaching Science: Hands-on Experiences

At the end of the semester which included their pre-student teaching field experiences and their science methods courses, all prospective teachers seem to value hands-on experiences as important to the meaningful learning and teaching of science. As Nancy completed her pre-student teaching, she had experienced some meaningful learning experiences with her students. She also had experienced the conceptual change model as a learner and a teacher and found the phases

helpful as she planned her science lessons for meaningful learning: "They are asked to discover a concept on their own by using the materials they are given. Having messed with the materials, students are able to think of some ideas and try them to see if they can find the concept out for themselves" (Post-philosophy, 12/12/97). Nancy realized that hands-on learning could be meaningful and she realized at least one model or way to help the teacher make hands-on activities more meaningful. As Nancy left pre-student teaching, she was looking forward to doing many hands-on science experiments in her student teaching experience.

Throughout his pre-student teaching field experience, Matt put into practice what he claimed as one of his beliefs: "They learn more from doing it themselves" (Interview 1, 10/24/97). For Matt, hands-on experiments were more conducive to meaningful learning than demonstrations. In addition to being hands-on, meaningful learning for Matt was making connections: "I'm a big fan on making connections. . .if you can make that connection. . .you'll never forget that" (Interview 1, 10/24/97). Within a hands-on activity about craters, Matt described meaningful learning as a particular student who had misconceptions before the lesson made her own connections between her existing ideas and the new evidence emerging from the hands-on activity: "After my craters lesson, she came up to me and said, 'I was completely wrong about the moon last week. Now I understand each phase and how craters got there on the moon.' And I never even lectured the 'facts' to her!" (Lesson Reflections, 11/19/97). As Matt finished his pre-student teaching and reflected on his entire experience, he had reinforced his belief of the importance of hands-on and meaningful experiences: "I understand now, more than ever, the importance of hands-on learning. Students need to learn to do science not just learn about science" (Post-philosophy, 12/12/97).

Learning and Teaching Science: Critical Thinking

Prawat (1992) cautions that one cannot equate activity with learning. Dewey (1938) also claimed that student engagement is not the best measure of educational value. Instead, teachers must connect content with the child's experience. As they completed their student teaching, most of the prospective teachers reinforced this belief that mere activity was important to meaningful learning, but it alone was not enough. Kris commented on meaningful learning: "Meaningful learning is that there is some sort of connection and it will last for awhile, a lot longer than rote learning" (Interview 6, 5/6/98). He also distinguished between fun and educational value within a journal entry following the making of paper mache planets for a science lesson: "While it was fun and motivating for some, I don't believe the educational value of this activity warrants my using it in the classroom for this purpose again. . .the educational value is lost" (Journal Entry, 2/26/98).

As the prospective teachers completed their last year of formal teacher preparation, they did not seem to be "naive constructivists" (Prawat, 1992, p. 357). At this point, they seemed to be distinguishing between mere activity and meaningful learning which involves hands-on activities plus thought. Kris gave meaningful learning two criteria: "Is there any connection they're making between what they already know and what they are learning currently, and are they going to remember it, not just two weeks from now, but two years from now, twenty years from now?" (Interview 6, 5/6/98). He seemed to sum up what all participants were expressing when he was asked about a revelation he had experienced over the course of student teaching: "The things that stick in their minds is when they do the hands-on, get involved, and it's not coming from the book or me just talking to them for half an hour. . . It's true. That's what they remember" (Interview 6, 5/6/98).

Learning and Teaching Science: Rote

If one were a successful rote learner, one would tend to not be as concerned with finding meaning in the learning process. Instead, one would tend to find an alternate way of completing the process if necessary. Nancy was a successful rote learner of science. When confronted with adversity, she learned to play the game to complete her experience. Some prospective teachers enter and leave a teacher preparation with little change in beliefs about learning and teaching science. Nancy seemed to be that type of prospective teacher in this study.

At the end of her student teaching experience, Nancy still viewed certain science knowledge as information that must be learned and the teacher as one who must distribute it: "There's certain material I really value and I think it's important that people know that information. . .I see the teacher as someone whose trying to get information out to learners and the only way to do that without a great deal of effort is to try and not make it as boring as it might be" (Interview 6, 5/7/98). Nancy firmly believed that certain material needed to be given by the teacher to the students so it was available for use by the students.

2b. The perceived safeness of learning to teach science depends on the environment created by the teacher.

During the first half of this study while the prospective teachers were in methods courses and in their pre-student teaching field experiences, this study focused largely on learning to teach science. The prospective teachers were largely in the role of learner in their methods courses and beginning their roles as teachers in their field experiences. As many were learning science concepts for the first time from their methods instructors, they were influenced to some extent by their teachers, the methods instructors.

Once the prospective teachers entered their student teaching placements, the context for interviews continued to focus on science teaching. However, because there was little control over how much or if science was taught in the student teaching placement classrooms, the context of responses to interview questions was different for each participant. Only Matt entered a classroom where the cooperating teacher was teaching science almost daily and shared the science teaching and learning philosophy of the university. Nancy and Kris entered classrooms where science was being taught from a more didactic orientation, while Carrie entered a classroom where science was not being taught at all.

Learning to Teach Science: Safe Learning Environment

As the prospective teachers finished their science methods course and their pre-student teaching field experience, they were largely focusing on their roles as learners and on the safe environment that they needed in which to learn. Their instructors had a great deal of influence on their learning environment at this point.

In her elementary science methods class, Nancy strengthened her belief that the teacher creates this environment conducive to learning: "It is amazing how. . .one class can change your whole outlook on a subject" (Post-philosophy, 12/12/97). She explained how she felt that occurred: "Prior to this semester, I did not believe I was capable of understanding science. . .[Instructor] made the room a safe place to discuss ideas and was extremely supportive in everything the class did" (Post-philosophy, 12/12/97). Nancy saw the impact a teacher can have on the meaningful learning experience of the student: "It is my belief that a large part of learning science depends on the teacher's enthusiasm. . .Students also feel more comfortable to ask questions when they are confused" (Pre-philosophy, 8/29/97).

The effect of this learning experience for Nancy and other prospective teachers was clear: "I was able to go from completely hating a subject to being excited to teach it" (Post-philosophy, 12/12/97). Again, Nancy's experience as a learner with a teacher who had a positive attitude not only toward teaching but also learning science reinforced her belief that the teacher was largely responsible for creating a positive learning environment. Teachers with a positive attitudes helped Nancy start to build a feeling of confidence in being able to not only understand science, but to teach science as well.

Learning to Teach Science: Cooperating Teacher

While prospective teachers held student-centered beliefs, they did not always put those beliefs into action. Overall, how the prospective teacher perceived the cooperating teacher and the rest of the learning-to-teach environment impacted how safe the prospective teacher felt to take

risks and learn to teach. In an environment perceived to be safe by the prospective teachers, he or she could take the opportunity to try new ideas and learn to teach. In an environment perceived not to be safe, the prospective teacher would compromise her or his beliefs. In addition, the cooperating teacher influenced whether the prospective teachers grew in learning to teach science, specifically.

Nancy entered her student teaching and immediately had a personality conflict with her cooperating teacher. Her process of learning to teach shut down as she started to focus on herself and her own survival of the field experience. Nancy entered a second student teaching placement, but she was still very cautious and self-centered.

While her new cooperating teacher was supportive, Nancy did not perceive of her learning environment as a safe place to take risks and try many new things. Instead, she chose to rely on what had worked for her in the past to be a successful learner. After all, she had boasted to teachers that she could get an 'A' in the class because she could successfully rote memorize and pass a test of that nature. In her placement, Nancy perceived that if she could please her cooperating teacher, she could complete student teaching without any further problems. She learned to play the game as she modeled her teaching behaviors after her cooperating teacher's. Her actions were largely determined by what she perceived would please her cooperating teacher and how unsafe she perceived her own learning environment to be.

While Nancy had some idea of meaningful learning, her experiences in her teacher education program did not seem to be adequate or sufficient to stimulate a significant conceptual change within her as she learned to teach. Nancy had reflected in-depth about learning to teach but her depression had led her to self-preservation and survival by following the rules of her cooperating teacher rather than risk creating any more conflict. Without a safe, risk free environment, Nancy was not free to grow, be creative, experiment, and learn. Without a lasting conceptual change, Nancy was teaching science as she was taught previous to her last year of teacher preparation. It is not impossible but is unlikely that if she ever teaches, she will remember the few positive experiences she once had with learning and teaching science, and teach from a constructivist perspective.

Carrie also crafted student-centered beliefs during her pre-student teaching experience. She perceived of her learning-to-teach environment both in her pre-student teaching and student teaching experiences as safe and supportive. Both of her cooperating teachers encouraged and supported her. However, Carrie did not progress much in learning to teach science beyond her pre-student teaching experience because she did not have a cooperating teacher who has able to reinforce and further develop her understandings of how children learn science. However, she did progress in learning to teach in general during her student teaching experience because she was

given the feeling of respect. This helped Carrie develop her confidence to learn and put her student-centered metaphors for teacher into action. The confidence in learning that Carrie developed led her to become a lifelong learner. Because she grew as a learner and teacher, I believe if she were given the opportunity to grow in her development as a science teacher, Carrie would probably continue to become a learner of teaching science.

Like Carrie, Matt also progressed in his process of learning to teach as he moved from his pre-student teaching into his student teaching placement largely due to a cooperating teacher who was supportive and respectful of his ability to learn to teach. She provided that safe, risk free environment that Matt needed. This was evident through his metaphor development. He crafted a metaphor for *learning to teach, like a kid in a candy shop*, and commented on the atmosphere his cooperating teacher created for him: "I love the freedom [cooperating teacher] is giving me in the classroom. She really makes me feel comfortable. She shows me how she can learn from me as well" (Journal Entry, 1/15/98).

However, unlike Carrie, Matt also progressed in his process of learning to teach science. His cooperating teacher was unique in that she taught science almost daily and shared Matt's constructivist philosophy of learning. Since Matt's conceptual development of constructivism was new, he benefited from a cooperating teacher who supported, encouraged, and helped him grow and develop. His environment for learning to teach was safe. Consequently, he took risks and tried new ideas. The more he experienced teaching and tried new ideas, the more he was able to generate creative ways to help his students learn science and other disciplines. Like Carrie, Matt, too, was on his way to becoming an independent learner of teaching. In addition, he was also further along in his development of becoming a learner of teaching science.

Kris entered his last year of formal teacher preparation with a clear idea of how science should be learned and taught. During both of his field experiences, Kris had supportive cooperating teachers who provided safe, risk free environments for him to learn to teach science and other disciplines. As an independent learner, Kris tackled obstacles as problems to be solved. Confident in himself as a learner of science, he was also confident in his ability to learn to teach science and other disciplines. He approached his field experience as another hands-on experience for him to learn from as he tried to construct an understanding of how to help children learn science. Individual reflection and also talking with others such as his parents, supervisor, and me helped Kris to make sense of his own learning process. Kris furthered his own development as a teacher of science much as an independent learner.

Main Assertion: Reflection through metaphor helped prospective teachers identify and actualize some of their beliefs about learning and teaching science, but the extent depended on their personal histories as science learners and their cooperating teachers.

In light of this, it seems that if prospective teachers need to make their implicit beliefs explicit before they can consider learning theories and teaching strategies as presented within their teacher education programs, then they need to be encouraged to do so within reflection. To help prospective teachers make their implicit beliefs about teaching and learning explicit so those beliefs can grow and develop into consistent actions throughout their personal and professional careers, metaphor may be a useful tool for the kind of reflection that connects learning and teaching. Underlying this whole process of learning to teach science is the learning-to-teach environment as influenced by the cooperating teacher. Prospective teachers apparently need safe and supportive learning-to-teach environments where they can become confident to learn to teach science under the mentorship of cooperating teachers who understand contemporary perspectives on children's science learning as well as how prospective teachers learn to teach.

Implications

Several implications for science teacher education emerged from this study. First, if science teacher education is viewed as a personal process of conceptual change, the importance of providing experiences that promote and support conceptual change within teacher education cannot be understated. When prospective teachers of science experience learning science content through a conceptual change approach and are aware of the process of their learning during the science experiences, they are more likely to view science learning as a process of conceptual change. Their experiences as learners in those settings seem to influence their orientations toward teaching science. In other words, if they have experienced conceptual change themselves in how science is learned and should be taught, they will more likely provide similar meaningful learning experiences for their students as well.

While experiencing the conceptual change approach as a learner in a methods course is a beginning for conceptual change within a prospective teacher, it alone is not sufficient. Prospective elementary teachers of science need to reinforce and develop their growing beliefs of learning and teaching within field experiences with cooperating teachers who share their constructivist philosophy of learning and teaching. In addition to sharing a constructivist philosophy, the cooperating teachers also need to be putting their beliefs into practice within their classrooms. For the prospective teacher to grow and develop in the process of learning to teach science, he or she also needs to be nurtured along by a cooperating teacher who is knowledgeable in how students learn science. Without this reinforcement, the prospective teacher is left to grow

on her or his own. For some, the growth will never progress and eventually digress as their personal histories of learning science move in to replace any new but temporary ideas.

In reality, it is unlikely that all prospective elementary teachers of science will be placed with cooperating teachers who are themselves able to nurture another along in the process of understanding how children learn science, especially when large numbers of prospective teachers enter and leave teacher preparation programs, as was the case in this study. To put that into practice requires a more intensive instructional relationship between the cooperating teacher and the prospective teacher, as well as among the university professors, cooperating teacher, and prospective teacher. To focus on quality over quantity, science teacher educators may need to prepare fewer, more qualified teachers. With fewer prospective teachers in a program, a more personalized approach to learning to teach science and other disciplines is possible.

An understanding of learning to teach science develops with personal experiences in teaching science from various orientations, professional development that includes the conceptual change approach, and collaboration with other science teachers committed to the same conceptual development. However, as with learning to teach in general, learning to teach science begins within a safe, risk free environment created by the cooperating teacher where prospective teachers can experience teaching, construct meanings from their experiences, and apply those beliefs to their classroom practice. They need to feel safe to be creative, to experiment, and to develop the confidence to become an independent, lifelong learner of learning and teaching.

From this study, it cannot be overstated that the role of the cooperating teacher seems crucial to the extent that the prospective teacher learns to teach science. If the prospective teacher perceives the cooperating teacher has created a supportive learning environment for trying new ideas and experimenting with teaching, the prospective teacher grows confident to learn. Consequently, the teacher also grows toward becoming a lifelong learner. If the prospective teacher perceives the environment is not safe, she or he will follow a course of action designed for survival of the immediate experience rather than for making meaning of the greater phenomenon of learning to teach. This points to the need for developing a consistent cadre of committed cooperating teachers who share the teaching and learning philosophy of the university teacher education program.

Experience alone is not enough, but is essential along with deep, metacognitive reflection both individually and with another whether that be a collaborator, supervisor, cooperating teacher, instructor, or peer who will encourage the individual to think more deeply about an idea. Purposeful reflection can be encouraged through a vehicle such as metaphor that helps prospective teachers make their implicit beliefs explicit in the form of a concrete image. Once prospective teachers are aware of their beliefs, they can then match them up with their actions; in other words,

put their beliefs into action. Reflection through metaphor seems to provide a way of helping prospective teachers recognize their teacher-centered actions and focus on teaching from a more student-centered perspective. By preparing fewer numbers of prospective teachers, science teacher educators provide a more personalized approach to teacher preparation.

This reflection can occur between a non-evaluative collaborator such as my role in this study, but more realistically within a cohort of student teachers who typically meet weekly with a supervisor. All of the prospective teachers in this study felt that if their supervision group had been more of an opportunity for them to share and challenge their ideas about learning and teaching, they would have better spent their time. At least two of the participants independently contacted me following the study to tell me they felt the experience of this project had helped them realize and articulate their thoughts. As a result, they were better prepared for their job interviews. Both had obtained employment shortly after the completion of this study.

All in all, prospective teachers of science need to be given the opportunity to experience conceptual change as learners. Since learning to teach is a conceptual change itself, the prospective teachers as learners need to first realize their prior knowledge or beliefs they hold about learning and teaching. The use of metaphor can serve as a tool for helping to make those implicit beliefs explicit. They also need to reinforce these developing beliefs as teachers within learning-to-teach environments supported by cooperating teachers who share the constructivist philosophy and who will encourage the conceptual development of the prospective teacher in learning to teach science.

Either way, it is essential that prospective teachers feel safe within their learning-to-teach environment so they can experience and experiment with putting their beliefs into action. Constantly reflecting both individually and in conversation with others through a tool such as metaphor can help prospective teachers align their beliefs and actions, monitor their changing beliefs, and construct their own meanings about this phenomenon of learning to teach science. If they leave the field experience with the confidence to learn, they will be on their way to becoming lifelong learners of teaching and learning.

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Figure 1. Summary of Assertions from Cross-case Analysis of Learning to Teach Science

MAIN ASSERTION: Reflection through metaphor helped prospective teachers identify and actualize some of their beliefs about learning and teaching science, but the extent depended on their personal histories as science learners and their cooperating teachers.

Assertion 1: Reflection with metaphor helped prospective teachers realize their beliefs and changing beliefs, some of which guided their practice.

- Reflection through metaphor helped prospective teachers make their beliefs explicit.
- Reflection through metaphor helped prospective teachers realize some important changes in their beliefs, some of which guided their practice.

Assertion 2: Learning to teach science depended on the prospective teacher's personal history as a science learner and the cooperating teacher.

- How one teaches science depends on how one learned science.
- The perceived safeness of learning to teach science depends on the environment created by the teacher.

Table 1. Summary of Concept Codes in Cross-case Analysis

Concept Code	Beginning of Pre-Student Teaching	End of Pre-Student Teaching	End of Student Teaching
Identify Beliefs with Metaphor		• Conceptual Change • Hands-on Experiences • Critical Thinking • Safe Learning Environment	
Identify Changing Beliefs with Metaphor			• Student Motivation • Foundation • Learning Community • Learning to Teach • Constraints
Learning and Teaching Science	• Meaningful • Rote	• Hands-on Experiences	• Critical Thinking • Rote
Learning to Teach Science		• Safe Learning Environment	• Cooperating Teacher

Table 2. Metaphors Crafted by Prospective Teachers

Identify Beliefs	Identify Changing Beliefs
<u>Conceptual Change</u> • Excited Child • Light Bulb • Amazed <u>Hands-on</u> • Trunk / Branches of a Tree • Provider of Experiences • Stagehand <u>Critical Thinking</u> • Facilitator of Thinking • Connection Maker <u>Safe Learning Environment</u> • Runway • Proud Parent • State Park	<u>Student Motivation</u> • One of the Students • Business Executive • Tour Guide <u>Foundation</u> • Open Book • Breakfast Cereal • Emotional • Quilt <u>Learning Community</u> • Parents as Park Committee <u>Learning to Teach</u> • Open Canvas • One of the Students <u>Constraints</u> • Self-centered